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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No. 8011-2

First Inventor or Application Identifier Fallon

Title SYSTEM AND METHODS FOR ACCELERATED DATA..

Express Mail Label No. EL192803145US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. ☒ Specification [Total Pages 51]
(preferred arrangement set forth below)
 - Descriptive title of the invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the invention
 - Brief Summary of the invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
3. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 20]
4. Oath or Declaration [Total Pages 2]
 - a. ☒ Newly executed (original or copy)
 - b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d))
(for continuation/divisional with Box 16 completed)
 - i. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting
inventor(s) named in the prior application,
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5. ☐ Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission
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 - a. ☐ Computer Readable Copy
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ACCOMPANYING APPLICATION PARTS

7. ☒ Assignment Papers (cover sheet & document(s))
8. ☐ 37 C.F.R. § 3.73(b) Statement ☒ Power of
(when there is an assignee) Attorney
9. ☐ English Translation Document (if applicable)
10. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS
Citations
11. ☐ Preliminary Amendment
12. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
13. ☒ Small Entity Statement(s) ☐ Statement filed in prior application,
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17. CORRESPONDENCE ADDRESS

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Applicant or Patentee: James J. Fallon

Serial or Patent No.: 0 / Unassigned

Filed or Issued: Concurrently herewith

For: SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL

**VERIFIED STATEMENT CLAIMING SMALL ENTITY
STATUS (37 CFR 1.9(f) and 1.27(c)) - SMALL BUSINESS CONCERN**

I hereby declare that I am

☐ the owner of the small business concern identified below:

☒ an official of the small business concern empowered to act on behalf of the
concern identified below:

NAME OF SMALL BUSINESS CONCERN Realtime Data Compression Systems, Incorporated

ADDRESS OF SMALL BUSINESS CONCERN 206 East 63rd Street, New York, New York 10021

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third-party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to, and remain with, the small business concern identified above, with regard to the invention described in

☒ the specification filed herewith.

☐ application serial no. 0 / _____, filed _____.

☐ patent no. _____, issued _____.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights in the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27).

Each such person, concern or organization having any rights in the invention is listed below:

- ☒ No such person, concern, or organization exists.
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I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small business entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING James J. Fallon

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ADDRESS OF PERSON SIGNING 1101 Midland Avenue, Bronxville, New York 10708

SIGNATURE _____

Date 3/2/99

SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL

BACKGROUND

5

1. Technical Field

The present invention relates generally to data storage and retrieval and, more particularly to systems and methods for improving data storage and retrieval bandwidth utilizing lossless data compression and decompression.

10

2. Description of the Related Art

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

15

Continuous information such as speech, music, audio, images and video frequently exists in the natural world as analog information. As is well-known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

20

There are many advantages associated with digital data representation.

For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossy and lossless data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Negentropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than that dictated by the negentropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio of the target

display device.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the negentropy of a given data set.

It is well known within the current art that data compression provides several unique benefits. First, data compression can reduce the time to transmit data by more efficiently utilizing low bandwidth data links. Second, data compression economizes on data storage and allows more information to be stored for a fixed memory size by representing information more efficiently.

One problem with the current art is that existing memory storage devices severely limit the performance of consumer, entertainment, office, workstation, servers, and mainframe computers for all disk and memory intensive operations. For example, magnetic disk mass storage devices currently employed in a variety of home, business, and scientific computing applications suffer from significant seek-time access delays along with profound read/write data rate limitations. Currently the fastest available (10,000) rpm disk drives support only a 17.1 Megabyte per second data rate (MB/sec). This is in stark contrast to the modern Personal Computer's Peripheral Component Interconnect (PCI) Bus's input/output capability of 264 MB/sec and internal local bus capability of 800 MB/sec.

Another problem within the current art is that emergent high performance disk interface standards such as the Small Computer Systems Interface (SCSI-3) and Fibre Channel offer only the promise of higher data transfer rates through intermediate data buffering in random access memory. These interconnect strategies do not address the fundamental problem that all modern magnetic disk storage devices for the personal computer marketplace are still limited by the same physical media restriction of 17.1 MB/sec. Faster disk access data rates are only achieved by the high cost solution of simultaneously accessing multiple disk drives with a technique known within the art as data striping.

Additional problems with bandwidth limitations similarly occur within the art by all other forms of sequential, pseudo-random, and random access mass storage devices. Typically mass storage devices include magnetic and optical tape, magnetic and optical disks, and various solid-state mass storage devices. It should be noted that the present invention applies to all forms and manners of memory devices including storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing accelerated data storage and retrieval by utilizing lossless data compression and decompression. The present invention provides an effective increase of the data storage and retrieval bandwidth of a memory storage device. In one aspect of the present invention, a method for providing accelerated data storage and retrieval comprises the

steps of:

receiving a data stream at an input data transmission rate which is greater than a data storage rate of a target storage device;

5 compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate;

storing the compressed data stream in the target storage device;

retrieving the compressed data stream from the target storage device at a rate equal to a data access rate of the target storage device; and

10 decompressing the compressed data at a decompression ratio to provide an output data stream having an output transmission rate which is greater than the data access rate of the target storage device.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a compression ratio that is at least equal to the ratio of the input data transmission rate to the data storage rate so as to provide
15 continuous storage of the input data stream at the input data transmission rate.

In another aspect of the present invention, the method for providing accelerated data storage and retrieval utilizes a decompression ratio which is equal to or greater than the ratio of the data access rate to a maximum accepted output data transmission rate so as to provide a continuous and optimal data output transmission rate.

20 In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a disk storage adapter to reduce the time required to store and retrieve data from computer to a disk memory device.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory.

In another aspect of the present invention a data storage and retrieval accelerator method and system is employed in a video data storage system to reduce the time required to store digital video data.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in a display controller to reduce the time required to send display data to the display controller or processor.

In another aspect of the present invention the data storage and retrieval accelerator method and system is employed in an input/output controller to reduce the time required to store, retrieve, or transmit data various forms of data.

The present invention is realized due to recent improvements in processing speed, inclusive of dedicated analog and digital hardware circuits, central processing units, digital signal processors, dedicated finite state machines (and any hybrid combinations thereof), that, coupled with advanced data compression and decompression algorithms, are enabling of ultra high bandwidth data compression and decompression methods that enable improved data storage and retrieval bandwidth.

These and other aspects, features and advantages, of the present invention will become apparent from the following detailed description of preferred embodiments, that is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a system for accelerated data storage and retrieval according to one embodiment of the present invention;

FIG. 2 is a flow diagram of a method for accelerated data storage in accordance with one aspect of the present invention;

FIG. 3 is a flow diagram of a method for accelerated data retrieval in accordance with one aspect of the present invention;

FIGS. 4a and 4b are timing diagrams of methods for accelerated data storage according to the present invention;

FIGS. 5a and 5b are timing diagrams of methods for accelerated data retrieval according to the present invention;

FIGS. 6a and 6b comprise a flow diagram of a method for accelerated data storage in accordance with a further aspect of the present invention;

FIGS. 7a and 7b comprise a flow diagram of a method for accelerated data retrieval in accordance with a further aspect of the present invention;

FIG. 8 is a detailed block diagram of a system for accelerated data storage according to a preferred embodiment of the present invention;

FIG. 9 is a detailed block diagram of a system for accelerated data retrieval according to a preferred embodiment of the present invention;

FIG. 10 is a block diagram of a system for accelerated video storage according to one embodiment of the present invention;

FIG. 11 is a block diagram of a system for accelerated retrieval of video

data according to one embodiment of the present invention;

FIG. 12 is a block diagram of an input/output controller system for accelerated storage of analog, digital, and serial data according to one embodiment of the present invention;

5 FIG. 13 is a flow diagram of a method for accelerated storage of analog, digital, and serial data according to one aspect of the present invention;

FIG. 14 is a block diagram of an input/output system for accelerated retrieval of analog, digital, and serial data according to one embodiment of the present invention; and

10 FIGS. 15a and 15b comprise a flow diagram of method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

15 The present invention is directed to systems and methods for providing improved data storage and retrieval bandwidth utilizing lossless data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be
20 implemented in various forms of hardware, software, firmware, or a combination thereof. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU) or digital signal processors

(DSP), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform may also include an operating system, microinstruction code, and dedicated processing hardware utilizing combinatorial logic or finite state machines. The various processes and functions described herein may be either part of the hardware, microinstruction code or application programs that are executed via the operating system, or any combination thereof.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in that the systems are programmed. It is to be appreciated that special purpose microprocessors, digital signal processors, dedicated hardware, or and combination thereof may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. 1, a block diagram illustrates a system for accelerated data storage and retrieval in accordance with an embodiment of the present invention. The system includes a data storage accelerator 10, operatively coupled to a data storage device 45. The data storage accelerator operates to increase the effective data storage rate of the data storage device 45. It is to be appreciated that the data storage device 45 may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The memory storage device 45 may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known

within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

The data storage accelerator 10 receives and processes data blocks from an input data stream. The data blocks may range in size from individual bits through complete files or collections of multiple files, and the data block size may be fixed or variable. In order to achieve continuous data storage acceleration, the data storage accelerator 10 must be configured to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Thus, to achieve optimum throughput, the rate that data blocks from the input data stream may be accepted by the data storage accelerator 10 is a function of the size of each input data block, the compression ratio achieved, and the bandwidth of the target storage device. For example, if the data storage device 45 (e.g., a typical target mass storage device) is capable of storing 20 megabytes per second and the data storage accelerator 10 is capable of providing an average compression ratio of 3:1, then 60 megabytes per second may be accepted as input and the data storage acceleration is precisely 3:1, equivalent to the average compression ratio.

It should be noted that it is not a requirement of the present invention to configure the storage accelerator 10 to compress a given input data block at a rate that is equal to or faster than receipt of the input data. Indeed, if the storage accelerator 10 compresses data at a rate that is less than the input data rate, buffering may be applied to

accept data from the input data stream for subsequent compression.

Additionally, it is not a requirement that the data storage accelerator 10 utilize data compression with a ratio that is at least the ratio of the input data stream to the data storage access rate of the data storage device 45. Indeed, if the compression ratio is less than this ratio, the input data stream may be periodically halted to effectively reduce the rate of the input data stream. Alternatively, the input data stream or the output of the data accelerator 10 may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to reduce the input data rate to rate that is equal to or slower than the ratio of the input data rate to the data storage device access rate by signaling the data input source and requesting a slower data input rate, if possible.

Referring again to FIG. 1, a data retrieval accelerator 80 is operatively connected to and receives data from the data storage device 45. The data retrieval accelerator 80 receives and processes compressed data from data storage device 45 in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator 80 is configured to decompress each compressed data block which is received from the data storage device 45. In order to achieve continuous accelerated data retrieval, the data retrieval accelerator must decompress a given input data block at a rate that is equal to or faster than receipt of the input data.

In a manner analogous to the data storage accelerator 10, achieving optimum throughput with the data retrieval accelerator 80 is a function of the rate that compressed data blocks are retrieved from the data storage device 45, the size of each

data block, the decompression ratio achieved, and the limitation on the bandwidth of the output data stream, if any. For example, if the data storage device 45 is capable of continuously supplying 20 megabytes per second and the data retrieval accelerator 80 is capable of providing an average decompression ratio of 1:3, then a 60 megabytes per second output data stream is achieved, and the corresponding data retrieval acceleration is precisely 1:3, equivalent to the average decompression ratio.

It is to be understood that it is not required that the data retrieval accelerator 80 utilize data decompression with a ratio that is at most equal to the ratio of the retrieval rate of the data storage device 45 to the maximum rate data output stream. Indeed, if the decompression ratio is greater than this ratio, retrieving data from the data storage device may be periodically halted to effectively reduce the rate of the output data stream to be at or below its maximum. Alternatively, the compressed data retrieved from the data storage device 45 or the output of the data decompressor may be buffered to temporarily accommodate the mismatch in data bandwidth. An additional alternative is to increase the output data rate by signaling or otherwise requesting the data output device(s) receiving the output data stream to accept a higher bandwidth, if possible.

Referring now to FIG. 2, a flow diagram of a method for accelerated data storage according to one aspect of the present invention illustrates the operation of the data storage acceleration shown in FIG. 1. As previously stated above, data compression is performed on a per data block basis. Accordingly, the initial input data block in the input data stream (step 200) is input into and compressed by the data storage accelerator 10 (step 202). Upon completion of the encoding of the input data block, the encoded data

block is then stored in the data storage device 45 (step 204). A check or other form of test is performed to see if there are additional data blocks available in the input stream (step 206). If no more data blocks are available, the storage acceleration process is terminated (step 208). If more data blocks are available in the input data stream, the next data block is received (step 210) and the process repeats beginning with data compression (step 202).

Referring now to FIG. 3, a flow diagram of a method for accelerated data retrieval according to one aspect of the present invention illustrates the operation of the data retrieval accelerator 80 shown in FIG. 1. Data decompression is also performed on a per data block basis. The initial compressed data block is retrieved from the storage device 45 (step 300) and is decompressed by the data retrieval accelerator 80 (step 302). Upon completion of the decoding of the initial data block, the decoded data block is then output for subsequent processing, storage, or transmittal (step 304). A check or other form of test is performed to see if additional data blocks available from the data storage device (step 306). If no more data blocks are available, the data retrieval acceleration process is terminated (step 308). If more data blocks are available from the data storage device, the next data block is retrieved (step 310) and the process repeats beginning with data decompression (step 302).

Referring now to FIGs. 4a and 4b, a timing diagram illustrates methods for accelerated data storage utilizing data compression in accordance with the present invention. Successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 is received from an input stream of one or more data blocks.

Similarly, data block 2 through data block n are received during time intervals T2 through Tn, respectively. For the purposes of discussion, FIG. 4a and 4b demonstrate one embodiment of the data storage utilizing a stream of n data blocks. As previously stated, the input data stream is comprised of one or more data blocks data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable.

In accordance with Method 1, compression of data block 1 and subsequent storage of the encoded data block 1 occurs within time interval T1. Similarly, the compression and storage of each successive data block occurs within the time interval the data block is received. Specifically, data blocks 2 ... n are compressed in time intervals T2 ... Tn, respectively, and the corresponding encoded data blocks 2 ... n are stored during the time intervals T2 ... Tn, respectively. It is to be understood that Method 1 relies on data compression and encoding techniques that process data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data compression techniques including, but not limited to, dictionary compression, run length encoding, null suppression and arithmetic compression are capable of encoding data when received. Method 1 possesses the advantage of introducing a minimum delay in the time from receipt of input to storage of encoded data blocks.

Referring again to FIG. 4a and 4b, Method 2 illustrates compressing and storing data utilizing pipelined data processing. For Method 2, successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 is received from an input stream of one or more data blocks during time interval T1. Similarly, data block

2 through data block n are received during time intervals T2 through Tn, respectively. Compression of data block 1 occurs during time interval T2 and the storage of encoded data block 1 occurs during time interval T3. As shown by Method 2, compression of each successive data block occurs within the next time interval after the data block is received and data storage of the corresponding encoded data block occur in the next time interval after completion of data compression.

The pipelining of Method 2, as shown, utilizes successive single time interval delays for data compression and data storage. Within the current invention, it is permissible to have increased pipelining to facilitate additional data processing or storage delays. For example, data compression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data compressors to process successive data blocks, e.g., data compression processing of a single data block through three successive time intervals requires three data compressors, each processing a successive input data block. Due to the principle of causality, encoded data blocks are output only after compression encoding.

Method 2 provides for block oriented processing of the input data blocks. Within the current art, block oriented data compression techniques provide the opportunity for increased data compression ratios. The disadvantage of Method 2 is increased delay from receipt of input data block to storage of encoded data. Depending on factors such as the size of input data blocks, the rate that they are received, the time required for data compression processing, the data compression ratio achieved, the

bandwidth of the data storage device, and the intended application, the delay may or may not be significant. For example, in a modern database system, recording data for archival purposes, the opportunity for increased data compression may far outweigh the need for minimum delay. Conversely, in systems such as a military real-time video targeting system, minimizing delay is often of the essence. It should be noted that Method 1 and Method 2 are not mutually exclusive, and may be utilized in any combination.

Referring now to FIGs. 5a and 5b, a timing diagram illustrates methods for accelerated data retrieval utilizing data decompression in accordance the present invention shown. Successive time intervals of equal duration are represented as T1 through T(n+2). Data block 1 is retrieved or otherwise accepted as input from one or more compressed data blocks retrieved from a data storage device. As shown, data block 2 through data block n are retrieved during time intervals T2 through Tn, respectively. For the purposes of discussion, FIG. 5a and 5b demonstrate one embodiment of the data retrieval accelerator utilizing a stream of n data blocks. Once again, the retrieved data stream is comprised of one or more data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the retrieved data block size may be fixed or variable.

In accordance with Method 1, decompression of data block 1 and subsequent outputting of the decoded data block 1 occurs within time interval T1. Similarly, decompression and outputting of each successive data block occurs within the time intervals they are retrieved. In particular, data block 2 through data block n are decompressed and decoded data block 2 through decoded data block n are output during

time intervals $T_2 \dots T_n$, respectively. It is to be understood that Method 1 relies on data decompression and decoding techniques that process compressed data as a contiguous stream, i.e., are not block oriented. It is well known within the current art that certain data decompression techniques including, but not limited to , dictionary compression, run length encoding, null suppression and arithmetic compression are capable of decoding data when received. Method 1 possesses the advantage of introducing a minimum delay in the time from retrieval of compressed data to output of decoded data blocks.

Referring again to FIG. 5a and 5b, Method 2 involves decompressing and outputting data utilizing pipelined data processing. For Method 2, successive time intervals of equal duration are represented as T_1 through $T_{(n+2)}$. Data block 1 through data block n are retrieved or otherwise accepted as input from a data storage device during time intervals T_1 through T_n , respectively. Decompression of data block 1 occurs during time interval T_2 and the decoded data block 1 is output during time interval T_3 . Similarly, decompression of each successive data block occurs within the next time interval after the data block is retrieved and the outputting of the decoded data block occurs during the next time interval after completion of data decompression.

The pipelining of Method 2, utilizes successive single time interval delays for data decompression and data output. Within the current invention, it is permissible to have increased pipelining to facilitate additional data retrieval or data decompression processing delays. For example, data decompression processing for a single input data block may utilize more than one time interval. Accommodating more than one time interval for data compression requires additional data decompressors to process

successive compressed data blocks, e.g., data decompression processing of a single data block through three successive time intervals requires three data decompressors, each processing a successive input data block. Due to the principle of causality, decoded data blocks are only output after decompression decoding.

5 As before, Method 2 provides for block oriented processing of the retrieved data blocks. Within the current art, block oriented data decompression techniques provide the opportunity to utilize data compression encoders that increase data compression ratios. The disadvantage of method 2 is increased delay from retrieval of compressed data block to output of decompressed data. As previously discussed for data
10 storage acceleration, depending on the size of retrieved data blocks, the rate that they are retrieved, the time required for data decompression processing, the data decompression ratio achieved, the bandwidth of the data output, and the intended application, the delay may or may not be significant.

 Referring now to FIGS. 6a and 6b, a flow diagram illustrates a method for
15 accelerated data storage according to a further aspect of the present invention. With this method, the data compression rate of the storage accelerator 10 is not required to be equal to or greater than the ratio of the input data rate to the data storage access rate. As previously stated above, data compression is performed on a per data block basis.

 Accordingly, the initial input data block in the input data stream is received (step 600)
20 and then timed and counted (step 602). Timing and counting enables determination of the bandwidth of the input data stream. The input data block is then buffered (step 604) and compressed by the data storage accelerator 10 (step 606). During and after the

encoding of the input data block, the encoded data block is then timed and counted (step 608), thus enabling determination of the compression ratio and compression bandwidth. The compressed, timed and counted data block is then buffered (step 610). The compression ratio and bandwidths of the input data stream and the encoder are then determined (step 612). The compressed data block is then stored in the data storage device 45 (step 614). Checks or other forms of testing are applied to ensure that the data bandwidths of the input data stream, data compressor, and data storage device are compatible (step 616). If the bandwidths are not compatible, then one or more system parameters may be modified to make the bandwidths compatible (step 618). For instance, the input bandwidth may be adjusted by either not accepting input data requests, lowering the duty cycle of input data requests, or by signaling one or more of the data sources that transmit the input data stream to request or mandate a lower data rate. In addition, the data compression ratio of the data storage accelerator 10 may be adjusted by applying a different type of encoding process such as employing a single encoder, multiple parallel or sequential encoders, or any combination thereof. Furthermore, additional temporary buffering of either the input data stream or the compressed data stream (or both) may be utilized.

By way of example, assuming the input data rate is 90 MB/sec and the data storage accelerator 10 provides a compression ration of 3:1, then the output of the data storage accelerator 10 would be 30 MB/sec. If the maximum data storage rate of the data storage device 45 is 20 MB/sec (which is less than the data rate output from the data storage accelerator 10), data congestion and backup would occur at the output of the data

storage accelerator 10. This problem may be solved by adjusting any one of the system parameters as discussed above, e.g., by adjusting the compression ratio to provide a data output rate from the data storage accelerator 10 to be equal to the data storage rate of the data storage device 45.

5 On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more of the system parameters), then a check or other form of test is performed to determine if there are additional data blocks available in the input stream (step 620). If no more data blocks are available, the storage acceleration process is terminated (step 622). If more data blocks are available in the input data stream, the next
10 data block is received (step 624) and the process repeats beginning with timing and counting of the input data block (step 602).

Referring now to FIGS. 7a and 7b, a flow diagram illustrates a method for accelerated data retrieval according to one aspect of the present invention. With this method, the data decompression ratio is not required to be less than or equal to the ratio
15 of the data retrieval access rate to the maximum output data rate. As previously stated above, data decompression is performed on a per data block basis. Accordingly, the initial input data block is retrieved from the storage device (step 700) and is timed and counted (step 702). Timing and counting enables determination of the bandwidth of data retrieval. The retrieved data block is then buffered (step 704) and decompressed by the
20 data retrieval accelerator 80 (step 706). During and after the decoding of the input data block, the decoded data block is then timed and counted (step 708), thus enabling determination of the decompression ratio and decompression bandwidth. The

any one of the system parameters as discussed above, e.g., by adjusting the decompression ratio to provide a data output rate from the data storage accelerator 80 to be equal to the maximum accepted output data transmission rate.

On the other hand, if the bandwidths are compatible (or made compatible by adjusting one or more system parameters), then a check or other form of test is performed to see if there are additional data blocks available from the data storage device (step 720). If no more data blocks are available for output, the retrieval acceleration process is terminated (step 722). If more data blocks are available to be retrieved from the data storage device, the next data block is retrieved (step 724) and the process repeats beginning with timing and counting of the retrieved data block (return to step 702).

It is to be understood that any conventional compression/decompression system and method (which comply with the above mentioned constraints) may be employed in the data storage accelerator 10 and data retrieval accelerator 80 for providing accelerated data storage and retrieval in accordance with the present invention.

Preferably, the present invention employs the data compression/decompression techniques disclosed in U.S. Serial No. 09/210,491 entitled "Content Independent Data Compression Method and System," filed on December 11, 1998, which is commonly assigned and which is fully incorporated herein by reference. It is to be appreciated that the compression and decompression systems and methods disclosed in U.S. Serial No. 09/210,491 are suitable for compressing and decompressing data at rates which provide accelerated data storage and retrieval.

Referring now to FIG. 8, a detailed block diagram illustrates a preferred

system for accelerated data storage which employs a compression system as disclosed in the above-incorporated U.S. Serial No. 09/210,491. In this embodiment, the data storage accelerator 10 accepts data blocks from an input data stream and stores the input data block in an input buffer or cache 15. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. A counter 20 counts or otherwise enumerates the size of input data block in any convenient units including bits, bytes, words, double words. It should be noted that the input buffer 15 and counter 20 are not required elements of the present invention. The input data buffer 15 may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an *a priori* specified minimum compression ratio threshold.

Data compression is performed by an encoder module 25 which may comprise a set of encoders E1, E2, E3 ... En. The encoder set E1, E2, E3 ... En may include any number "n" (where n may =1) of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module 25 successively receives as input each of the buffered
 input data blocks (or unbuffered input data blocks from the counter module 20). Data
 compression is performed by the encoder module 25 wherein each of the encoders E1
 En processes a given input data block and outputs a corresponding set of encoded data
 5 blocks. It is to be appreciated that the system affords a user the option to enable/disable
 any one or more of the encoders E1.... En prior to operation. As is understood by those
 skilled in the art, such feature allows the user to tailor the operation of the data
 compression system for specific applications. It is to be further appreciated that the
 encoding process may be performed either in parallel or sequentially. In particular, the
 10 encoders E1 through En of encoder module 25 may operate in parallel (i.e.,
 simultaneously processing a given input data block by utilizing task multiplexing on a
 single central processor, via dedicated hardware, by executing on a plurality of processor
 or dedicated hardware systems, or any combination thereof). In addition, encoders E1
 through En may operate sequentially on a given unbuffered or buffered input data block.
 15 This process is intended to eliminate the complexity and additional processing overhead
 associated with multiplexing concurrent encoding techniques on a single central
 processor and/or dedicated hardware, set of central processors and/or dedicated hardware,
 or any achievable combination. It is to be further appreciated that encoders of the
 identical type may be applied in parallel to enhance encoding speed. For instance,
 20 encoder E1 may comprise two parallel Huffman encoders for parallel processing of an
 input data block.

A buffer/counter module 30 is operatively connected to the encoder

module 25 for buffering and counting the size of each of the encoded data blocks output from encoder module 25. Specifically, the buffer/counter 30 comprises a plurality of buffer/counters BC1, BC2, BC3 ...BCn, each operatively associated with a corresponding one of the encoders E1...En. A compression ratio module 35, operatively connected to the output buffer/counter 30, determines the compression ratio obtained for each of the enabled encoders E1...En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC1 ... BCn. In addition, the compression ratio module 35 compares each compression ratio with an *a priori*-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E1...En achieves a compression that exceeds an *a priori*-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module 38, operatively coupled to the compression ratio module 35, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block. A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along

with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal. If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit, then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto. A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal.

The data storage acceleration device 10 is connected to a data storage device interface 40. The function of the data storage interface 40 is to facilitate the formatting and transfer of data to one or more data storage devices 45. The data storage interface may be any of the data interfaces known to those skilled in the art such as SCSI (Small Computer Systems Interface), Fibre Channel, "Firewire", IEEE P1394, SSA (Serial Storage Architecture), IDE (Integrated Disk Electronics), and ATA/ATAPI interfaces. It should be noted that the storage device data interface 40 is not required for implementing the present invention. As before, the data storage device 45 may be any form of memory device including all forms of sequential, pseudo-random, and random access storage devices. The data storage device 45 may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory (RAM), magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices (e.g.,

ATA/ATAPI IDE disk). Thus it should be noted that the current invention applies to all forms and manners of memory devices including, but not limited to, storage devices utilizing magnetic, optical, and chemical techniques, or any combination thereof.

Again, it is to be understood that the embodiment of the data storage accelerator 10 of FIG. 8 is exemplary of a preferred compression system which may be implemented in the present invention, and that other compression systems and methods known to those skilled in the art may be employed for providing accelerated data storage in accordance with the teachings herein. Indeed, in another embodiment of the compression system disclosed in the above-incorporated U.S. Serial No. 09/210,491, a timer is included to measure the time elapsed during the encoding process against an *a priori*-specified time limit. When the time limit expires, only the data output from those encoders (in the encoder module 25) that have completed the present encoding cycle are compared to determine the encoded data with the highest compression ratio. The time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved. In addition, the results from each encoder in the encoder module 25 may be buffered to allow additional encoders to be sequentially applied to the output of the previous encoder, yielding a more optimal lossless data compression ratio. Such techniques are discussed in greater detail in the above-incorporated U.S. Serial No. 09/210,491.

Referring now to FIG. 9, a detailed block diagram illustrates a preferred system for accelerated data retrieval employing a decompression system as disclosed in the above-incorporated U.S. Serial No. 09/210,491. In this embodiment, the data

retrieval accelerator 80 retrieves or otherwise accepts data blocks from one or more data storage devices 45 and inputs the data via a data storage interface 50. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files.

5 Additionally, the input data block size may be fixed or variable. As stated above, the memory storage device 45 may be volatile or non-volatile in nature, or any combination thereof. Storage devices as known within the current art include all forms of random access memory, magnetic and optical tape, magnetic and optical disks, along with various other forms of solid-state mass storage devices. Thus it should be noted that the current invention applies to all forms and manners of memory devices including storage devices
10 utilizing magnetic, optical, and chemical techniques, or any combination thereof. The data storage device interface 50 converts the input data from the storage device format to a format useful for data decompression.

The storage device data interface 50 is operatively connected to the data
15 retrieval accelerator 80 which is utilized for decoding the stored (compressed) data, thus providing accelerated retrieval of stored data. In this embodiment, the data retrieval accelerator 80 comprises an input buffer 55 which receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files.

20 Additionally, the data block size may be fixed or variable. The input data buffer 55 is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module 60 receives the buffered (or

unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module 65 includes one or more decoders D1...Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D1...Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source.

As with the data compression systems discussed in U.S. Application Serial No. 09/210,491, the decoder module 65 may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time. The data retrieval accelerator 80 also includes an output data buffer or cache 70 for buffering the decoded data block output from the decoder module 65. The output buffer 70 then provides data to the output data stream. It is to be appreciated by those skilled in the art that the data retrieval

accelerator 80 may also include an input data counter and output data counter operatively coupled to the input and output, respectively, of the decoder module 65. In this manner, the compressed and corresponding decompressed data block may be counted to ensure that sufficient decompression is obtained for the input data block.

5 Again, it is to be understood that the embodiment of the data retrieval accelerator 80 of FIG. 9 is exemplary of a preferred decompression system and method which may be implemented in the present invention, and that other data decompression systems and methods known to those skilled in the art may be employed for providing accelerated data retrieval in accordance with the teachings herein.

10 In accordance with another aspect of the present invention, the data storage and retrieval accelerator system and method may be employed in for increasing the storage rate of video data. In particular, referring now to FIG. 10, a block diagram illustrates a system for providing accelerated video data storage in accordance with one embodiment of the present invention. The video data storage acceleration system accepts
15 as input one or more video data streams that are analog, digital, or any combination thereof in nature. The input multiplexer 1010 selects the initial video data stream for data compression and acceleration. The input multiplexer 1010 is operatively connected to an analog to digital converter 1020 which converts analog video inputs to digital format of desired resolution. The analog to digital converter 1020 may also include functions to
20 strip video data synchronization to perform other data formatting functions. It should be noted that the analog to digital conversion process is not required for digital video inputs. The analog to digital converter 1020 is operatively connected a video memory 1030 that

is, in turn, operatively connected to a video processor 1040. The video processor 1040 performs manipulation of the digital video data in accordance with any user desired processing functions. The video processor 1040 is operatively coupled to a video output memory 1050, that is operatively connected to a data storage accelerator 10 which
5 compresses the video data to provide accelerated video data to the output data stream for subsequent data processing, storage, or transmittal of the video data. This video data acceleration process is repeated for all data blocks in the input data stream. If more video data blocks are available in the input data stream, the video multiplexer selects the next block of video for accelerated processing. Again, it is to be understood that the data
10 storage accelerator 10 may employ any compression system which is capable of compressing data at a rate suitable for providing accelerated video data storage in accordance with the teachings herein.

In accordance with another aspect of the present invention, the accelerated data storage and retrieval system may be employed in a display controller to reduce the
15 time required to send display data to a display controller or processor. In particular, referring now to FIG. 11, a block diagram illustrates a display accelerator system in accordance with one embodiment of the present invention. The video display accelerator accepts as input one or more digital display data blocks from an input display data stream. It is to be understood that the system processes the input data stream in data blocks that
20 may range in size from individual bits through complete files or collections of multiple files. Additionally, the input video data block size may be fixed or variable. The input data blocks are processed by a data retrieval accelerator 80 which employs a data

decompression system in accordance with the teachings herein. Upon completion of data
decompression, the decompressed data block is then output to a display memory 1110
that provides data to a display processor 1120. The display processor 1120 performs any
user desired processing function. It is well known within the current art that display data
5 is often provided in one or more symbolic formats such as Open Graphics Language
(Open GL) or another display or image language. The display processor 1120 is
operatively connected an output memory buffer 1130. The output memory 1130 supplies
data to a display formatter 1140 that converts the data to a format compatible with the
output display device or devices. Data from the display formatter 1140 is provided to the
10 display driver 1150 that outputs data in appropriate format and drive signal levels to one
or more display devices. It should be noted that the display memory 1110, display
processor 1120, output memory 1130, display formatter 1140, and display driver 1150 are
not required elements of the present invention.

In accordance with yet another aspect of the present invention, the data
15 storage and retrieval accelerator system and method may be employed in an I/O controller
to reduce the time for storing, retrieving or transmitting parallel data streams. In
particular, referring now to FIG. 12, a block diagram illustrates a system for accelerated
data storage of analog, digital, and serial data in accordance with one embodiment of the
present invention. The data storage accelerator 10 is capable of accepting one or more
20 simultaneous analog, parallel digital, and serial data inputs. An analog input multiplexer
1205 selects the initial analog data for data compression and acceleration. The analog
input multiplexer 1205 is operatively connected to an analog to digital converter 1210

that converts the analog input signal to digital data of the desired resolution. The digitized data output of the analog to digital converter 1210 is stored in an analog data memory buffer 1215 for subsequent data storage acceleration. Similarly, a parallel digital data input multiplexer 1220 selects the initial parallel digital data for data compression and acceleration. The parallel digital data input multiplexer 1220 is operatively connected to an input data latch 1225 that holds the input parallel digital data. The parallel digital data is then stored in digital data memory buffer 1245 for subsequent data storage acceleration. In addition, a serial digital data input multiplexer 1235 selects the initial serial digital data for data compression and acceleration. The serial digital data input multiplexer 1235 is operatively connected to a serial data interface 1240 that converts the serial data stream to a format useful for data acceleration. The formatted serial digital data is then stored in serial data memory buffer 1245 for subsequent data acceleration. The analog data memory 1215, parallel digital data memory 1230, and serial data memory 1245 are operatively connected to the data storage accelerator device 10. Data is selected from each data memory subsystem based upon a user defined algorithm or other selection criteria. It should be noted that the analog input multiplexer 1205, analog to digital converter 1210, analog data memory 1215, parallel data input multiplexer 1220, data latch 1225, digital data memory 1230, serial data input multiplexer 1235, serial data interface 1240, serial data memory 1245, and counter 20 are not required elements of the present invention. As stated above, the data storage accelerator 10 employs any of the data compression methods disclosed in the above-incorporated U.S. Serial No. 09/210,491, or any conventional data compression method suitable for

compressing data at a rate necessary for obtaining accelerated data storage. The data storage accelerator supplies accelerated data to the output data stream for subsequent data processing, storage, or transmittal.

Referring now to FIG. 13, a flow diagram illustrates a method for accelerated data storage of analog, digital, and serial data according to one aspect of the present invention. The analog input multiplexer selects the initial analog data for data compression and acceleration (step 1300). The analog input multiplexer provides analog data to the analog to digital converter that converts the analog input signal to digital data of the desired resolution (step 1302). The digitized data output of the analog to digital converter is then buffered in the analog data memory buffer (step 1304) for subsequent data acceleration. Similarly, the parallel digital data multiplexer selects the initial parallel digital data for data compression and acceleration (step 1306). The parallel digital data multiplexer provides data to the input data latch that then holds the input parallel digital data (step 1308). The parallel digital data is then stored in digital data memory buffer for subsequent data acceleration (step 1310). The serial digital data input multiplexer selects the initial serial digital data for data compression and acceleration (step 1312). The serial digital data input multiplexer provides serial data to the serial data interface that converts the serial data stream to a format useful for data acceleration (step 1314). The formatted serial digital data is then stored in the serial data memory buffer for subsequent data acceleration (step 1316). A test or other check is performed to see if new analog data is available (step 1318). If no new analog data is available a second check is performed to see if new parallel data is available (step 1320). If no new parallel data is available, a

third test is performed to see if new serial data is available (step 1322). If no new serial data is available (step 1322) the test sequence repeats with the test for new analog data (step 1318). If new analog data block is available (step 1318), or if new parallel data block is available (step 1320), or if new serial data block is available (step 1322), the input data block is compressed by the data storage accelerator (step 1324) utilizing any compression method suitable for providing accelerated data storage in accordance with the teachings herein. After data compression is complete, the compressed data block is then output subsequent accelerated data processing, storage, or transmittal (step 1326). After outputting data the process repeats beginning with a test for new analog data (return to step 1318).

Referring now to FIG. 14, a block diagram illustrates a system for accelerated retrieval of analog, digital, and serial data in accordance with one embodiment of the present invention. A data retrieval accelerator 80 receives data from an input data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the input data block size may be fixed or variable. The data retrieval accelerator 80 decompresses the input data utilizing any of the decompression methods suitable for providing accelerated data retrieval in accordance with the teachings herein. The data retrieval accelerator 80 is operatively connected to analog data memory 1405, digital data memory 1420, and serial data memory 1435. Dependent upon the type of input data block, the decoded data block is stored in the appropriate analog 1405, digital 1420, or serial 1435 data memory.

The analog data memory 1405 is operatively connected to a digital to analog converter 1410 that converts the decompressed digital data block into an analog signal. The digital to analog converter 1410 is further operatively connected to an analog hold and output driver 1415. The analog hold and output driver 1415 demultiplexes the analog signal output from the digital to analog converter 1410, samples and holds the analog data, and buffers the output analog data.

In a similar manner, the digital data memory 1420 is operatively connected to a digital data demultiplexer 1425 that routes the decompressed parallel digital data to the output data latch and driver 1430. The output latch and driver 1430 holds the digital data and buffers the parallel digital output.

Likewise, the serial data memory 1435 is operatively connected to a serial data interface 1440 that converts the decompressed data block to an output serial data stream. The serial data interface 1440 is further operatively connected to the serial demultiplexer and driver 1445 that routes the serial digital data to the appropriate output and buffers the serial data output.

Referring now to FIGs. 15a and 15b, a flow diagram illustrates a method for accelerated retrieval of analog, digital, and serial data according to one aspect of the present invention. An initial data block is received (step 1500) and then decompressed by the data storage retrieval accelerator (step 1502). Upon completion of data decompression, a test or other check is performed to see if the data block is digitized analog data (step 1508). If the data block is not digitized analog data, a second check is performed to see if the data block is parallel digital data (step 1510). If the data block is

not parallel digital data, a third test is performed to see if the data block serial data (step 1512). The result of at least one of the three tests will be affirmative.

If the data block is comprised of digitized analog data, the decoded data block is buffered in an “analog” digital data memory (step 1514). The decoded data block is then converted to an analog signal by a digital to analog converter (step 1520). The analog signal is then output (step 1522).

If the data block is comprised of parallel digital data, the decoded data block is buffered in a “parallel” digital data memory (step 1516). The decoded data block is then demultiplexed (step 1524) and routed to the appropriate the output data latch and driver. The output latch and driver then holds the digital data and buffers the parallel digital output (step 1526).

If the data block is comprised of serial data, the decoded data block is buffered in “serial” digital data memory (step 1518). The decoded data is then formatted to a serial data format (step 1528). The serial data is then demultiplexed, routed to the appropriate output, and output to a buffer (step 1530).

Upon output of analog data (step 1522), parallel digital data (step 1526), or serial digital data (step 1530), a test or other form of check is performed for more data blocks in the input stream (step 1532). If no more data blocks are available, the test repeats (return to step 1532). If a data block is available, the next data block is received (step 1534) and the process repeats beginning with step 1502.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention

is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A program storage device readable by machine, tangibly embodying a program of instructions executable by the machine to perform method steps for providing accelerated data storage and retrieval, said method steps comprising:

5 receiving a data stream at an input data transmission rate which is greater than a data storage rate of a target storage device;

compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate; and

storing the compressed data stream in the target storage device.

10 2. The program storage device of claim 1, wherein the compression ratio is at least equal to the ratio of the input data transmission rate to the data storage rate so as to provide continuous storage of the input data stream at the input data transmission rate.

15 3. The program storage device of claim 1, further including instructions for performing the steps of:

determining the input data transmission rate and the data compression rate;

comparing the input data transmission rate, the data compression rate and the data storage rate to determine if they are compatible; and

20 adjusting one or more parameters to obtain compatibility between the input data transmission rate, the data compression rate and the data storage rate, if they are determined to be incompatible.

4. The program storage device of claim 3, wherein the instructions for performing the adjusting step include instructions for performing one of adjusting the input data transmission rate, adjusting the compression ratio and a combination thereof.

5. The program storage device of claim 4, wherein the instructions for performing the adjusting step further include instructions for temporarily buffering one of the input data stream, the compressed data stream, and a combination thereof.

6. The program storage device of claim 1, further including instructions for performing the steps of:

retrieving the compressed data stream from the target storage device at a rate equal to a data access rate of the target storage device; and

decompressing the compressed data at a decompression ratio to provide an output data stream having an output transmission rate which is greater than the data access rate of the target storage device.

7. The program storage device of claim 6, wherein the decompression ratio is equal to the ratio of the data access rate to the input data transmission rate so as to obtain an output data transmission rate which is equal to the input data transmission rate.

8. The program storage device of claim 6, wherein the decompression ratio is equal to or greater than the ratio of the data access rate to a maximum accepted output data transmission rate so as to provide a continuous and optimal data output transmission rate.

5

9. The program storage device of claim 6, further including instructions for performing the steps of:

determining the data retrieval rate and the data decompression rate;

comparing the data retrieval rate, the data decompression rate and the

10

output data transmission rate to determine if they are compatible; and

adjusting one or more parameters to obtain compatibility between the data retrieval rate, the data decompression rate and the output data transmission rate if they are determined to be incompatible.

15

10. The program storage device of claim 9, wherein the instructions for performing the adjusting step include instructions for performing one of adjusting the data retrieval rate, adjusting the decompression ratio, and a combination thereof.

20

11. The program storage device of claim 9, wherein the instructions for performing the adjusting step include instructions for temporarily buffering one of the retrieved data stream, the decompressed data stream, and a combination thereof.

12. The program storage device of claim 6, wherein the input data

stream and the compressed data stream retrieved from the target storage device comprise one of a single data block and a plurality of data blocks.

13. The program storage device of claim 12, wherein the instructions
5 for performing the compression step include instructions for performing the steps of:

(a) compressing an input data block with a plurality of encoders to provide
a set of encoded data blocks;

(b) determining a compression ratio for each of the encoded data blocks;

(c) comparing each compression ratio with an *a priori* specified
10 compression threshold;

(d) selecting for output an encoded data block in the set having the highest
compression ratio and appending a corresponding descriptor, if at least one of the
compression ratios exceeds the *a priori* specified compression threshold; and

(e) repeating steps (a) through (d) for each successive input data block.
15

14. The program storage device of claim 13, further including
instructions for selecting for output the input data block and appending a null descriptor
to the input data block is all of the compression ratios of the corresponding encoded data
blocks fall below the *a priori* compression limit

15. The program storage device of claim 13, wherein the instructions for the compressing step include instructions for simultaneously compressing the data block with a plurality of encoders in parallel.

5 16. The program storage device of claim 13 wherein the instructions for performing the compressing step include instructions for sequentially compressing the data block with the plurality of encoders.

10 17. The program storage device of claim 12, wherein the instructions for performing the decompressing step include instructions for performing the steps of:

- (a) extracting an encoding type descriptor from an input data block;
- (b) decompressing the data block in accordance with a decoder corresponding to the extracted descriptor; and
- (c) repeating steps (a) and (b) for each successive input data block.

15 18. The program storage device of claim 17, further including instructions for outputting the input data block if the extracted descriptor is a null descriptor.

19. A system for accelerating the rate of data storage and retrieval of a data storage device, comprising:

means for receiving a data stream having an input data transmission rate which is greater than a data storage rate of the data storage device; and

5 means for compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate; and

means for storing the compressed data stream in the data storage device.

20. The system of claim 19, wherein the compression ratio is at least
10 equal to the ratio of the input data transmission rate to the data storage rate so as to provide continuous storage of the input data stream at the input data transmission rate.

21. The system of claim 19, further comprising:

15 means for receiving the compressed data stream from the storage device at a rate equal to a data access rate of the storage device; and

means for decompressing the compressed data at a decompression ratio that provides an output data stream having an output transmission rate which is greater than the data access rate of the storage device.

22. The system of claim 21, wherein the decompression ratio is equal
20 to the ratio of the data access rate to the input data transmission rate so as to obtain an output data transmission rate which is equal to the input data transmission rate.

23. The system of claim 19, wherein the data storage device is random access memory (RAM) device.

24. The system of claim 19, wherein the data storage device is one of a magnetic disk mass storage device, an optical mass storage device, a chemical mass storage device, and a combination thereof.

25. The system of claim 21, further including a data storage interface device for converting the compressed data stream to a format suitable for storage in the storage device and for converting the stored compressed data to a format suitable for decompression.

26. The system of claim 19, wherein the input data stream is a video data stream received from a video data processing system operatively connected to the receiving means.

27. The system of claim 21, further including a display controller system operatively connected to the decompression means, wherein the output data stream comprises a video data stream for processing by the display controller system.

28. The system of claim 19, further including an input/output controller system having a plurality of input/output ports, operatively connected to the compression means, wherein the input data stream comprises one of serial digital data, parallel digital data, analog data, and a selected combination thereof.

5

29. The system of claim 21, further including an input/output controller system having a plurality of input/output ports, operatively connected to the decompression means, wherein the output data stream comprises one of serial digital data, parallel digital data, analog data, and a selected combination thereof.

10

30. A method for providing accelerated data storage and retrieval, comprising the steps of:

receiving a data stream at an input data transmission rate which is greater than a data storage rate of a target storage device;

15

compressing the data stream at a compression ratio which provides a data compression rate that is greater than the data storage rate; and

storing the compressed data stream in the target storage device.

31. The method of claim 30, wherein the compression ratio is at least equal to the ratio of the input data transmission rate to the data storage rate so as to provide continuous storage of the input data stream at the input data transmission rate.

20

32. The method of claim 30, further including the steps of:
determining the input data transmission rate and the data compression rate;
comparing the input data transmission rate, the data compression rate and
the data storage rate to determine if they are compatible; and
5 adjusting one or more parameters to obtain compatibility between the
input data transmission rate, the data compression rate and the data storage rate, if they
are determined to be incompatible.

33. The method of claim 32, wherein the adjusting step includes one of
10 adjusting the input data transmission rate, adjusting the compression ratio, and a
combination thereof.

34. The method of claim 32, wherein the adjusting step includes
temporarily buffering one of the input data stream, the compressed data stream, and a
15 combination thereof.

35. The method of claim 30, further including the steps of:
retrieving the compressed data stream from the target storage device at a
rate equal to a data access rate of the target storage device; and
20 decompressing the compressed data at a decompression ratio to provide an
output data stream having an output transmission rate which is greater than the data
access rate of the target storage device.

36. The method of claim 35, wherein the decompression ratio is equal to the ratio of the data access rate to the input data transmission rate so as to obtain an output data transmission rate which is equal to the input data transmission rate.

5 37. The method of claim 35, wherein the decompression ratio is equal to or greater than the ratio of the data access rate to a maximum accepted output data transmission rate so as to provide a continuous and optimal data output transmission rate.

10 38. The method of claim 35, further including the steps of:
determining the data retrieval rate and the data decompression rate;
comparing the data retrieval rate, the data decompression rate and the
output data transmission rate to determine if they are compatible; and
adjusting one or more parameters to obtain compatibility between the data
15 retrieval rate, the data decompression rate and the output data transmission rate if they are
determined to be incompatible.

20 39. The method of claim 38, wherein the adjusting step includes one of
adjusting the data retrieval rate, adjusting the decompression ratio, and a combination
thereof.

40. The method of claim 38, wherein the adjusting step includes temporarily buffering one of the retrieved data stream, the decompressed data stream, and a combination thereof.

5 41. The method of claim 35, wherein the input data stream and the compressed data stream retrieved from the storage device comprise one of a single data block and a plurality of data blocks.

10 42. The method of claim 41, wherein the compression step includes the steps of:

(a) compressing an input data block with a plurality of encoders to provide a set of encoded data blocks;

(b) determining a compression ratio for each of the encoded data blocks;

15 (c) comparing each compression ratio with an *a priori* specified compression threshold;

(d) selecting for output an encoded data block in the set having the highest compression ratio and appending a corresponding descriptor, if at least one of the compression ratios exceeds the *a priori* specified compression threshold; and

(e) repeating steps (a) through (d) for each successive input data block.

43. The method of claim 42, further including the step of selecting for output the input data block and appending a null descriptor to the input data block is all of the compression ratios of the corresponding encoded data blocks fall below the *a priori* compression limit

5

44. The method of claim 42, wherein the compressing step includes the step of simultaneously compressing the data block with a plurality of encoders in parallel.

45. The method of claim 42 wherein the compressing step includes the step of sequentially compressing the data block with the plurality of encoders.

10

46. The method of claim 41, wherein the decompressing step includes the steps of:

(d) extracting an encoding type descriptor from an input data block;

(e) decompressing the data block in accordance with a decoder corresponding to the extracted descriptor; and

(f) repeating steps (a) and (b) for each successive input data block.

47. The method of claim 46, further including the step of outputting the input data block if the extracted descriptor is a null descriptor.

20

ABSTRACT OF THE DISCLOSURE

Systems and methods for providing accelerated data storage and retrieval utilizing lossless data compression and decompression. A data storage accelerator includes one or a plurality of high speed data compression encoders that are configured to simultaneously or sequentially losslessly compress data at a rate equivalent to or faster than the transmission rate of an input data stream. The compressed data is subsequently stored in a target memory or other storage device whose input data storage bandwidth is lower than the original input data stream bandwidth. Similarly, a data retrieval accelerator includes one or a plurality of high speed data decompression decoders that are configured to simultaneously or sequentially losslessly decompress data at a rate equivalent to or faster than the input data stream from the target memory or storage device. The decompressed data is then output at rate data that is greater than the output rate from the target memory or data storage device. The data storage and retrieval accelerator method and system may employed: in a disk storage adapter to reduce the time required to store and retrieve data from computer to disk; in conjunction with random access memory to reduce the time required to store and retrieve data from random access memory; in a display controller to reduce the time required to send display data to the display controller or processor; and/or in an input/output controller to reduce the time required to store, retrieve, or transmit data.

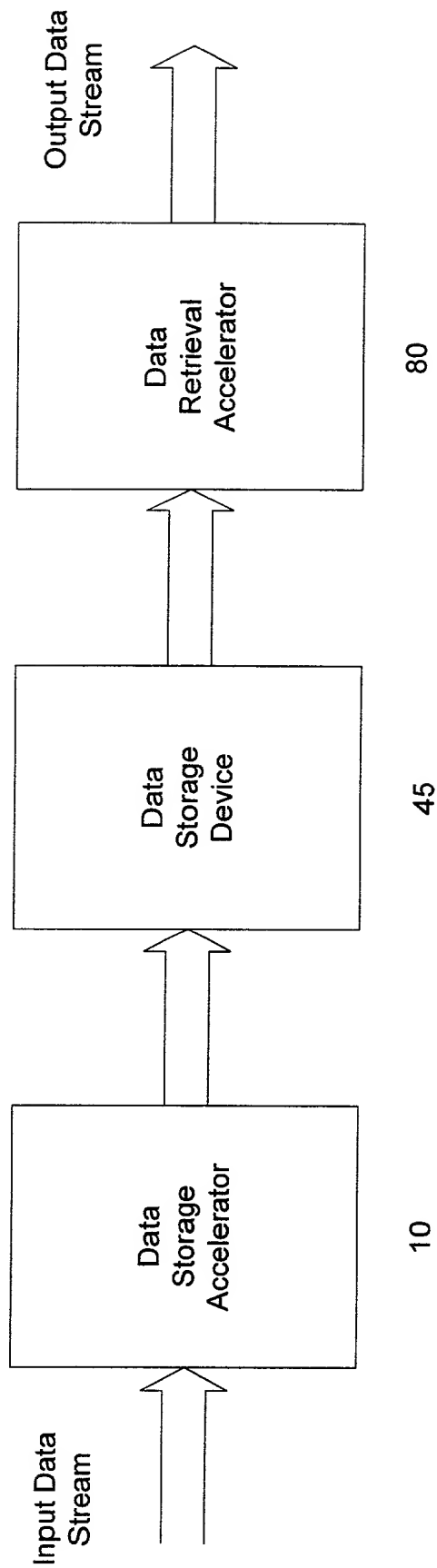


FIGURE 1

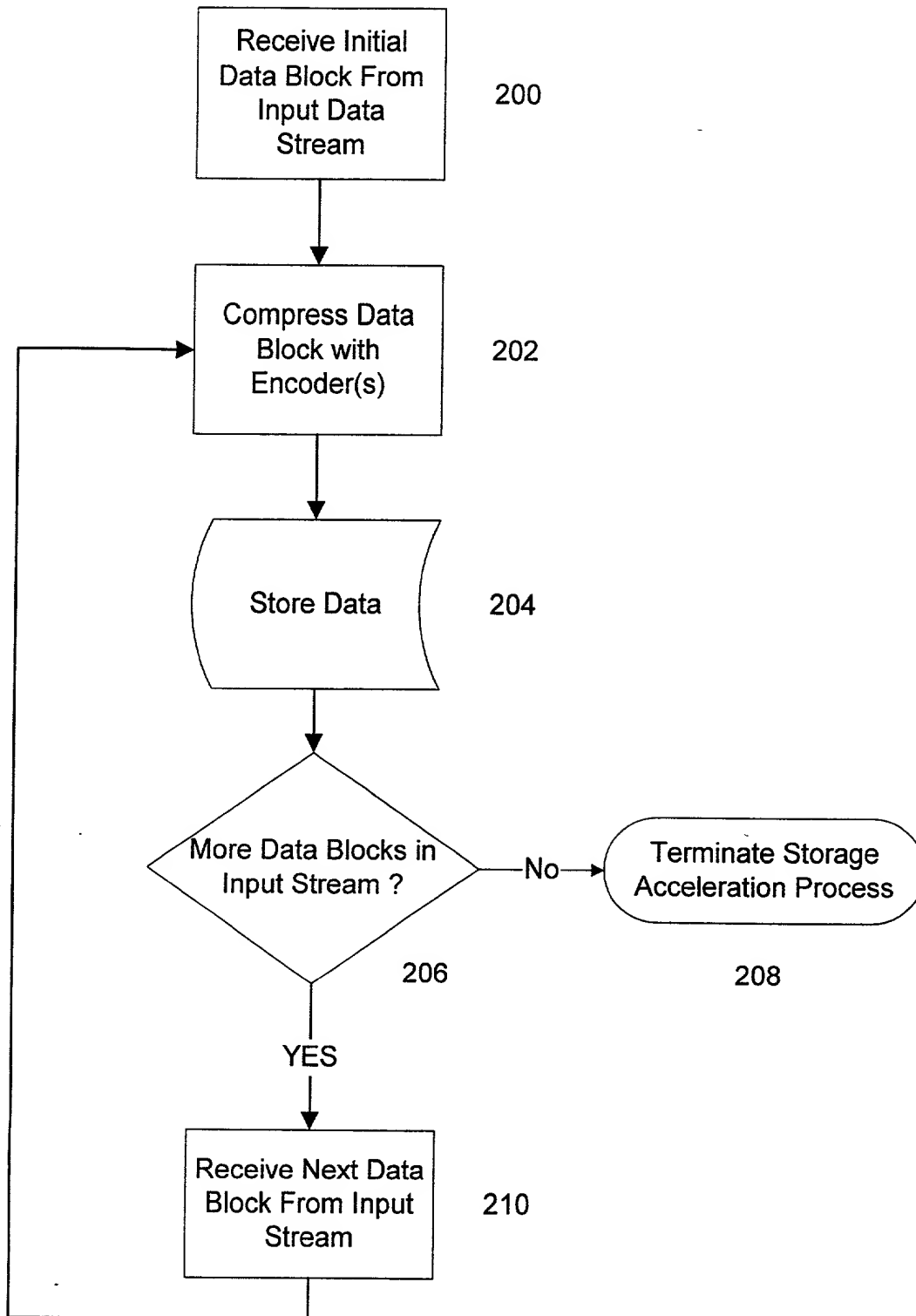


FIGURE 2

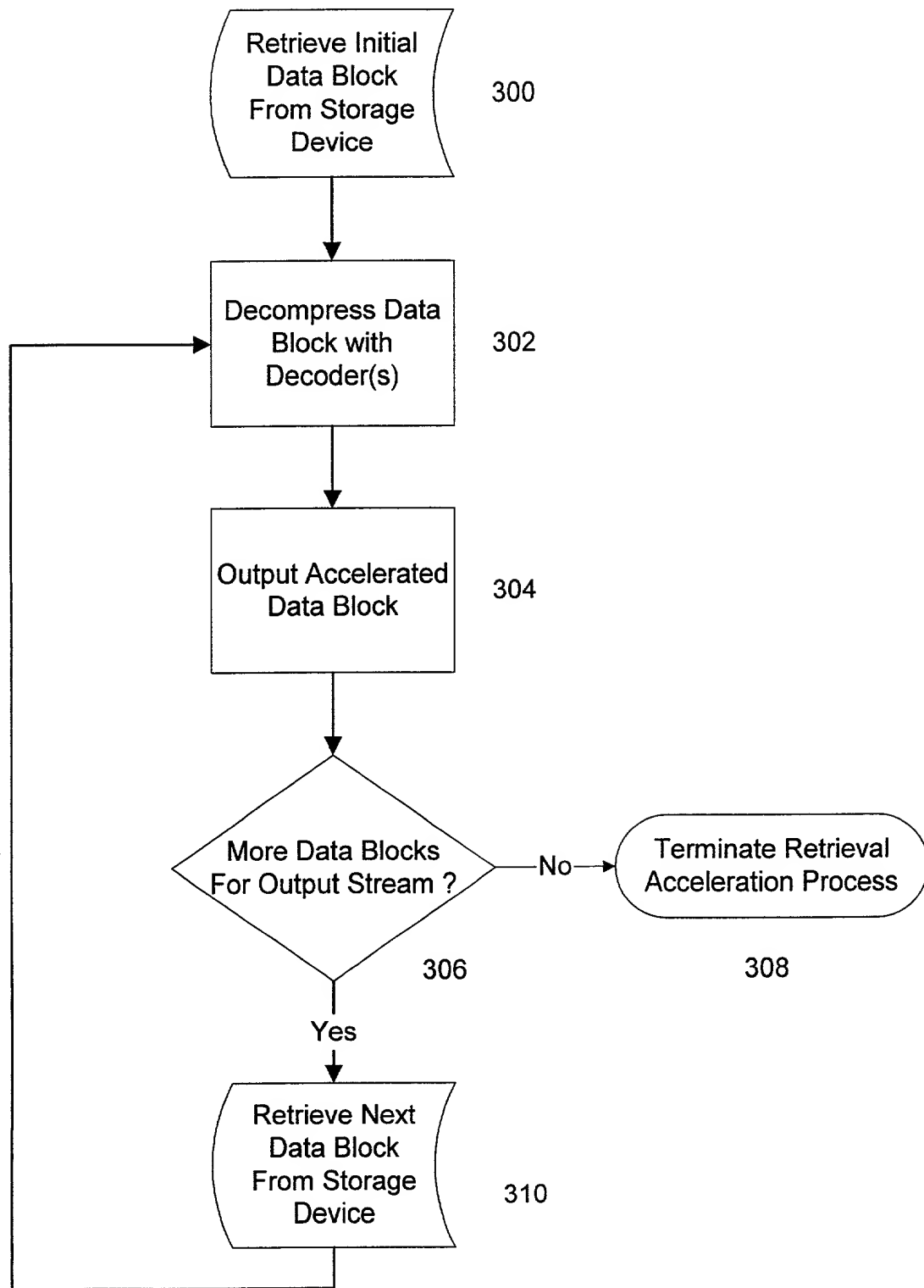


FIGURE 3

Time Interval	T1	T2	T3	T4	Ti
Receive Data Block	Receive Data Block 1	Receive Data Block 2	Receive Data Block 3	Receive Data Block 4	Receive Data Block i
<u>METHOD 1</u>					
Compress Data Block	Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block 4	Compress Data Block i
Store Encoded Data Block	Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block 3	Store Encoded Data Block 4	Store Encoded Data Block i
<u>METHOD 2</u>					
Compress Data Block		Compress Data Block 1	Compress Data Block 2	Compress Data Block 3	Compress Data Block (i-1)
Store Encoded Data Block			Store Encoded Data Block 1	Store Encoded Data Block 2	Store Encoded Data Block (i-2)

FIGURE 4a

Time Interval	T(i+1)	T(i+2)	T _n	T(n+1)	T(n+2)
Receive Data Block	Receive Data Block (i+1)	Receive Data Block (i+2)	Receive Data Block _n		
<u>METHOD 1</u>					
Compress Data Block	Compress Data Block (i+1)	Compress Data Block (i+2)	Compress Data Block _n		
Store Encoded Data Block	Store Encoded Data Block (i+1)	Store Encoded Data Block (i+2)	Store Encoded Data Block _n		
<u>METHOD 2</u>					
Compress Data Block	Compress Data Block _i	Compress Data Block (i+1)	Compress Data Block (n-1)	Compress Data Block _n	
Store Encoded Data Block	Store Encoded Data Block (i-1)	Store Encoded Data Block _i	Store Encoded Data Block (n-2)	Store Encoded Data Block (n-1)	Store Encoded Data Block _n

FIGURE 4b

Time Interval	T1	T2	T3	T4	T _i
Retrieve Data Block	Retrieve Data Block 1	Retrieve Data Block 2	Retrieve Data Block 3	Retrieve Data Block 4	Retrieve Data Block i
<u>METHOD 1</u>					
Decompress Data Block	Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block 4	Decompress Data Block i
Output Decoded Data Block	Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block 3	Output Decoded Data Block 4	Output Decoded Data Block i
<u>METHOD 2</u>					
Decompress Data Block		Decompress Data Block 1	Decompress Data Block 2	Decompress Data Block 3	Decompress Data Block (i-1)
Output Decoded Data Block			Output Decoded Data Block 1	Output Decoded Data Block 2	Output Decoded Data Block (i-2)

FIGURE 5a

Time Interval	T(i+1)	T(i+2)	T _n	T(n+1)	T(n+2)
Retrieve Data Block	Retrieve Data Block (i+1)	Retrieve Data Block (i+2)	Retrieve Data Block _n		
<u>METHOD 1</u>					
Decompress Data Block	Decompress Data Block (i+1)	Decompress Data Block (i+2)	Decompress Data Block _n		
Output Decoded Data Block	Output Decoded Data Block (i+1)	Output Decoded Data Block (i+2)	Output Decoded Data Block _n		
<u>METHOD 2</u>					
Decompress Data Block	Decompress Data Block _i	Decompress Data Block (i+1)	Decompress Data Block (n-1)	Decompress Data Block _n	
Output Decoded Data Block	Output Decoded Data Block (i-1)	Output Decoded Data Block _i	Output Decoded Data Block (n-2)	Output Decoded Data Block (n-1)	Output Decoded Data Block _n

FIGURE 5b

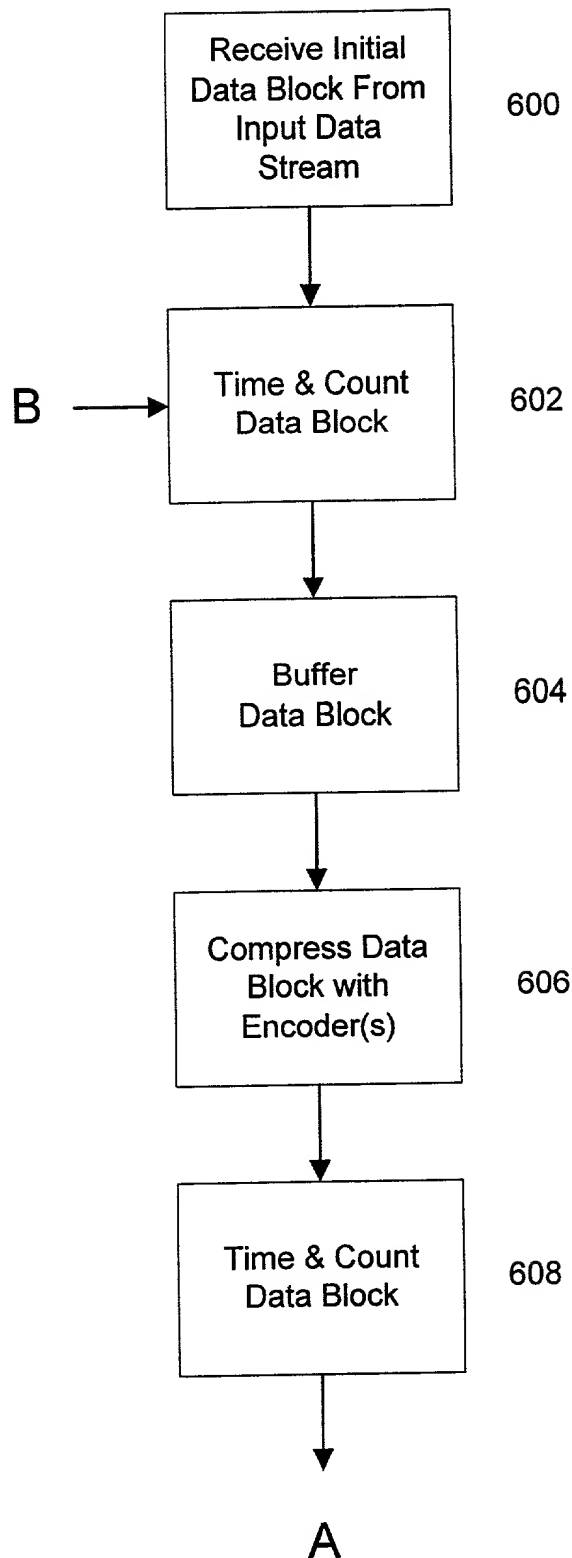


FIGURE 6a

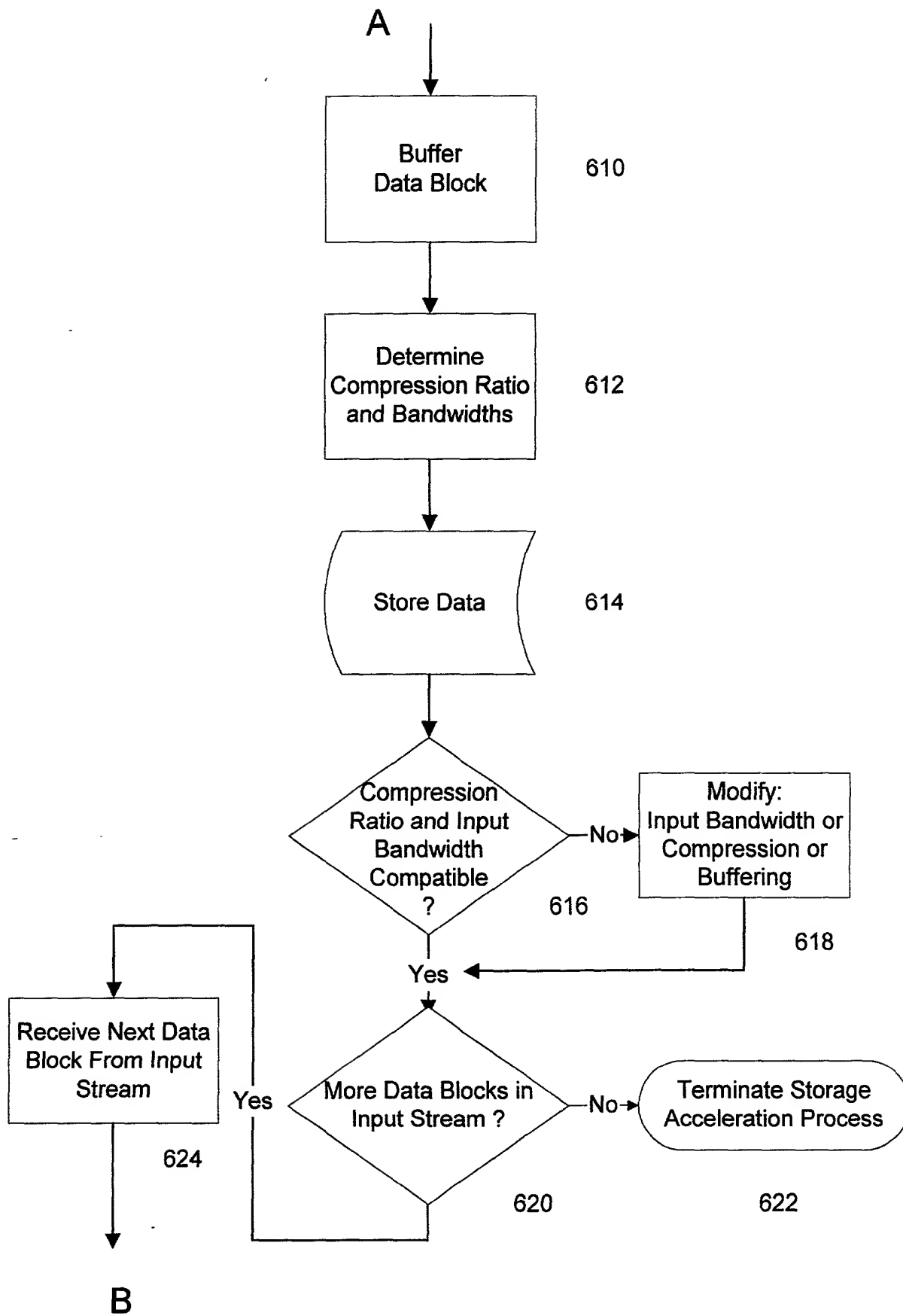


FIGURE 6b

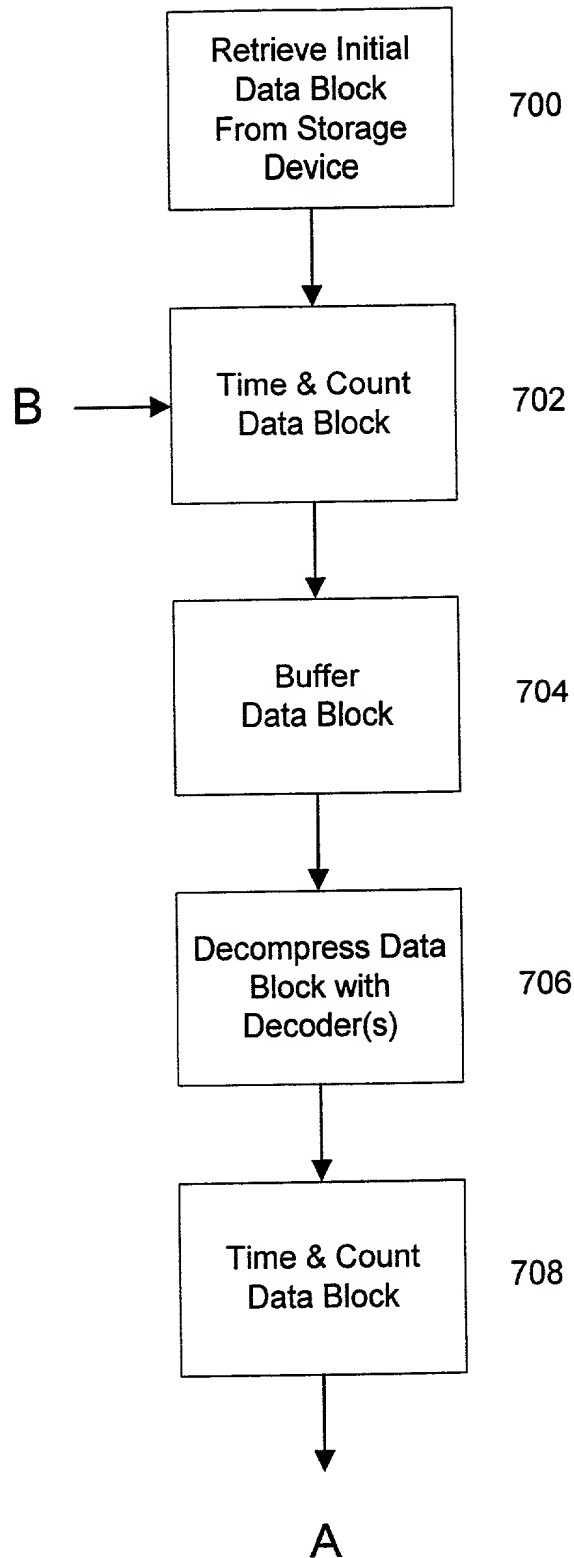


FIGURE 7a

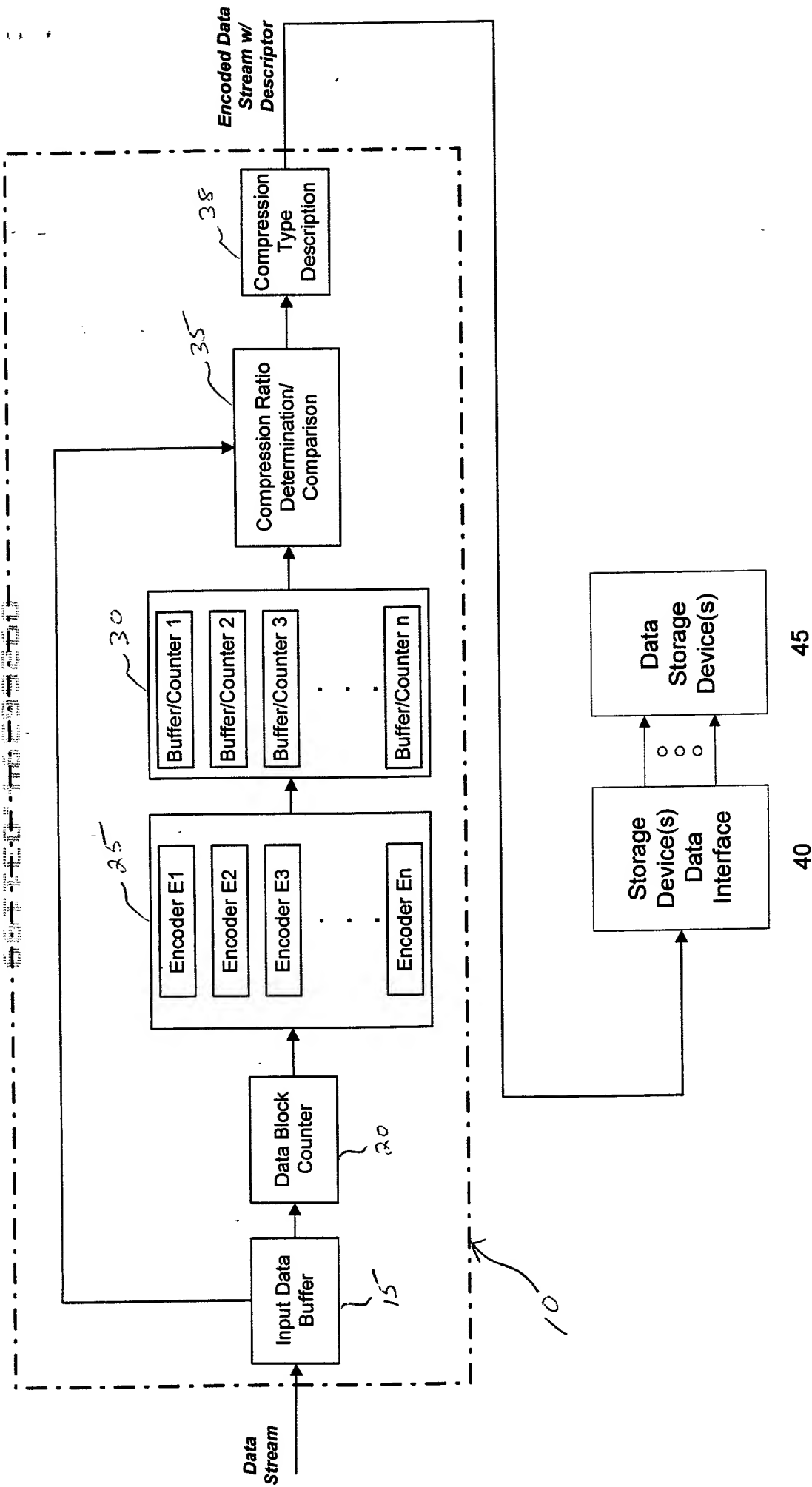


FIGURE 8

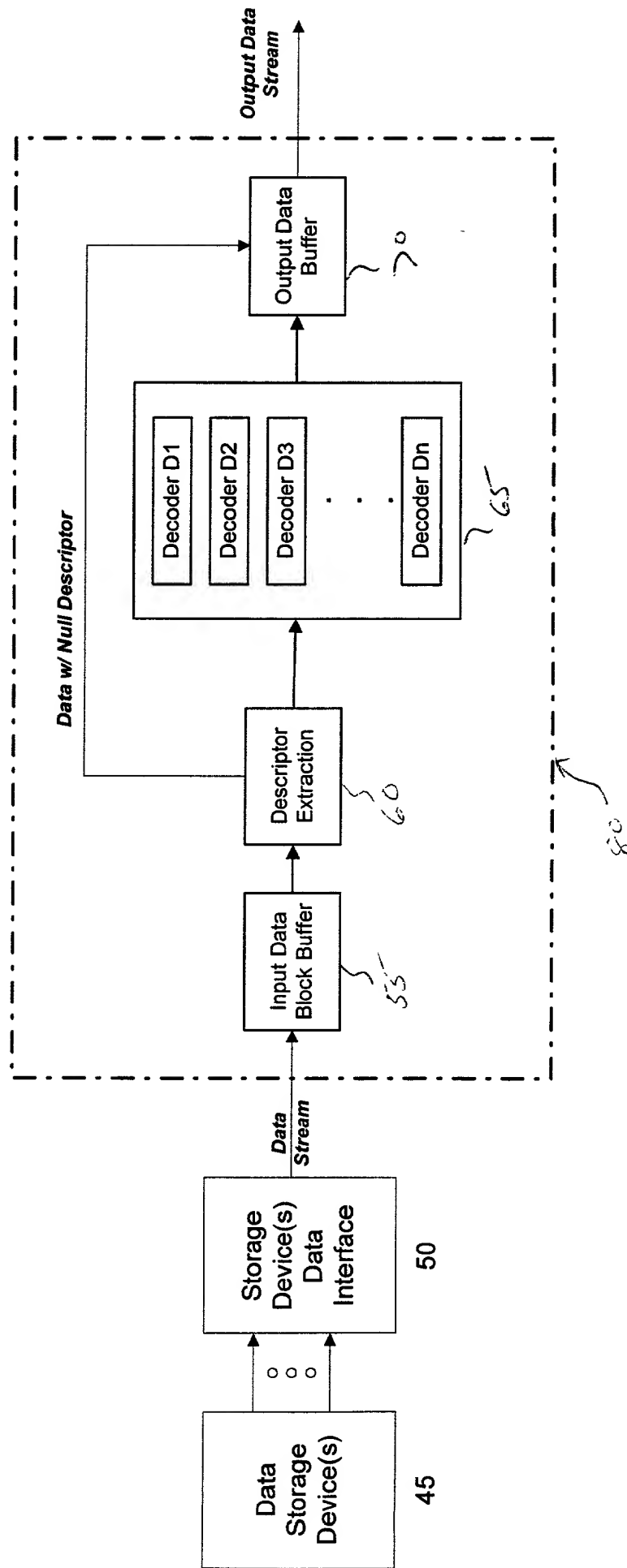


FIG. 9

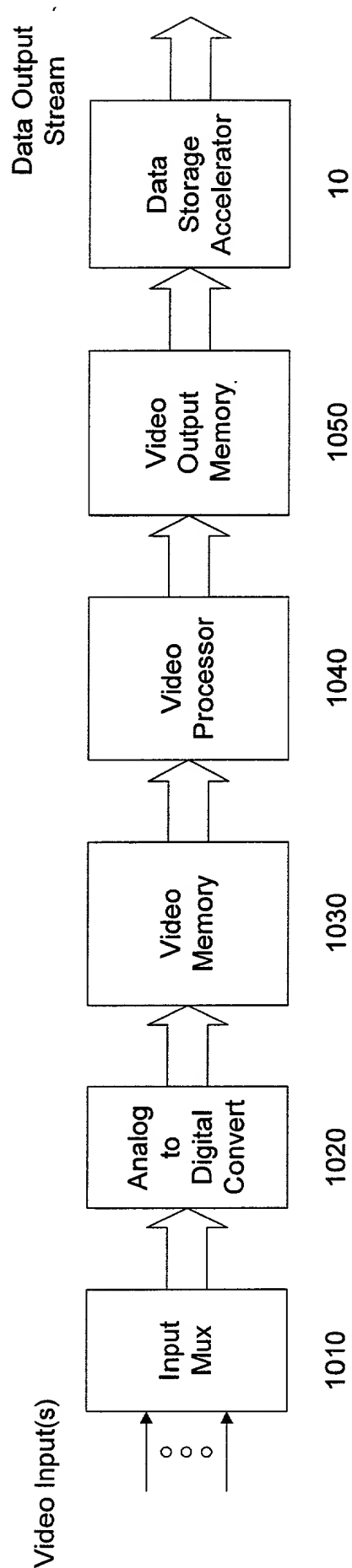


FIGURE 10

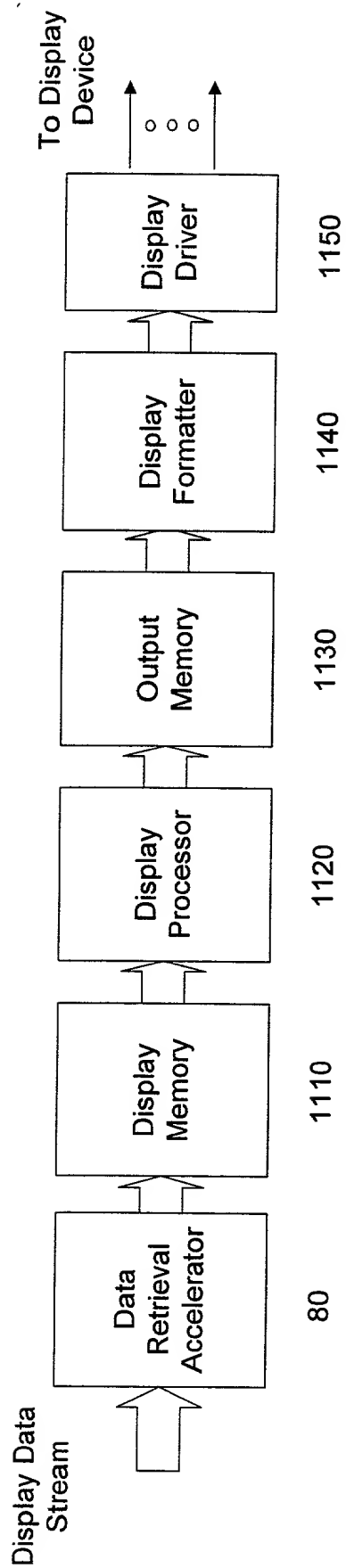


FIGURE 11

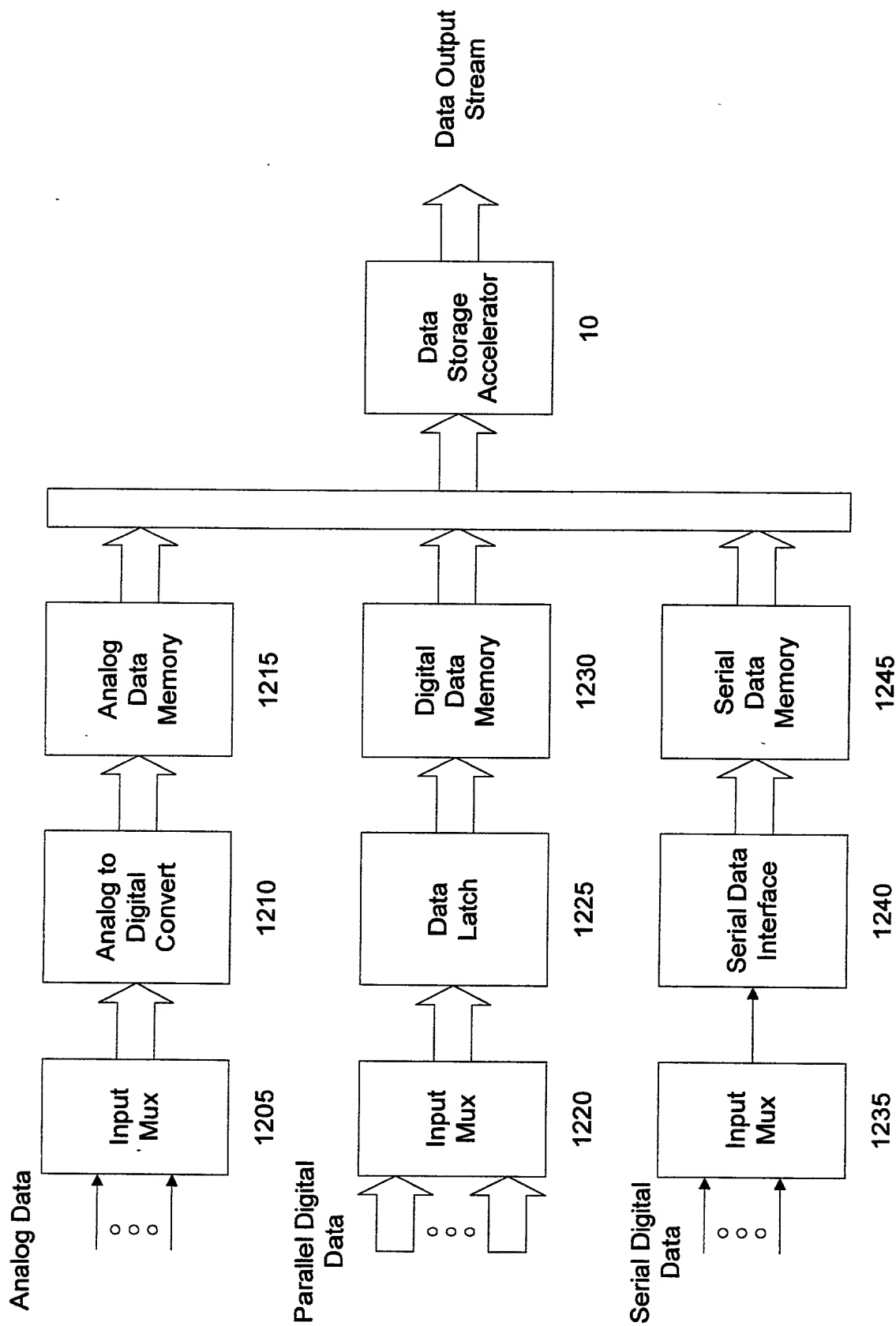


FIGURE 12

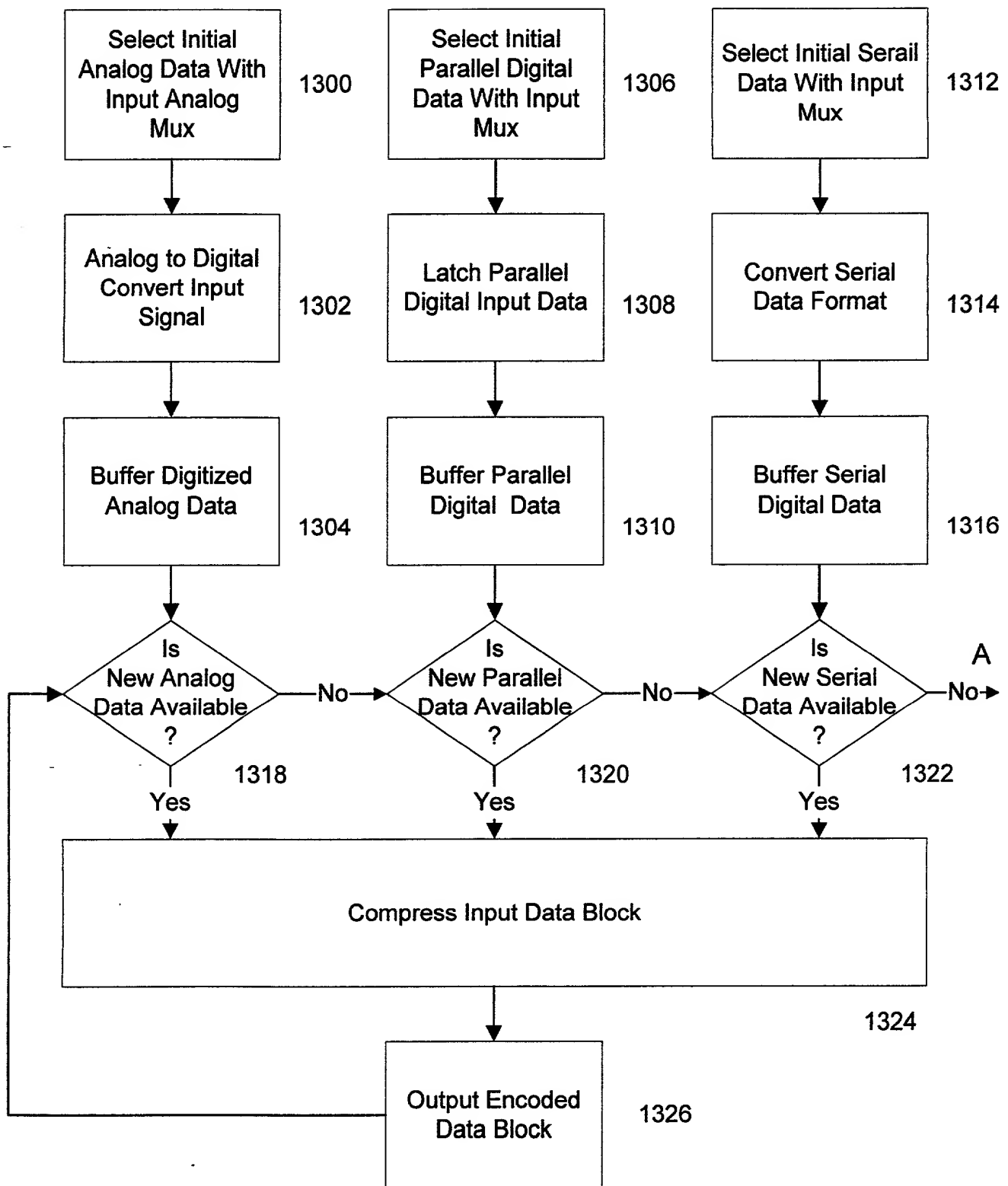


FIGURE 13

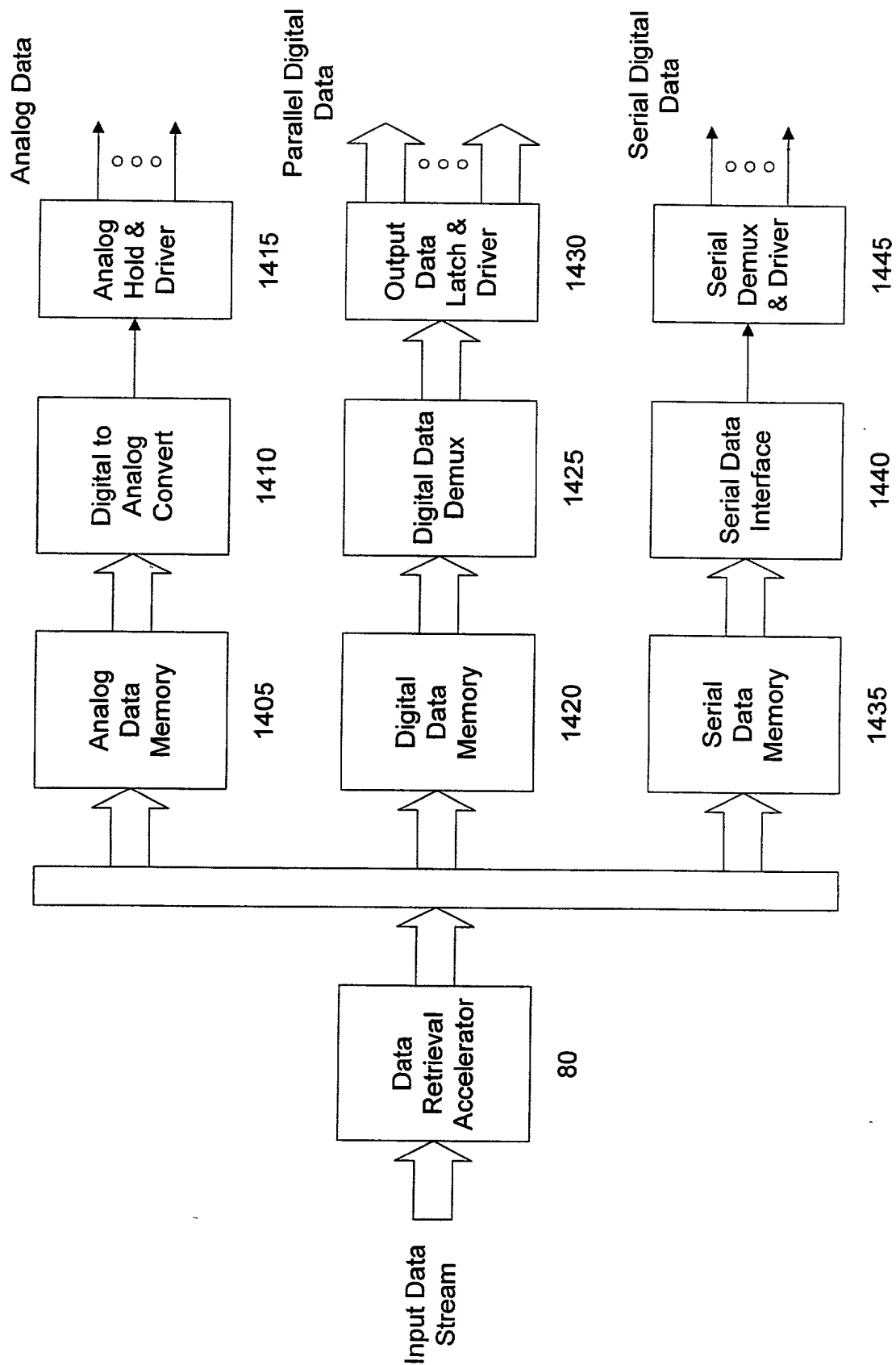


FIGURE 14

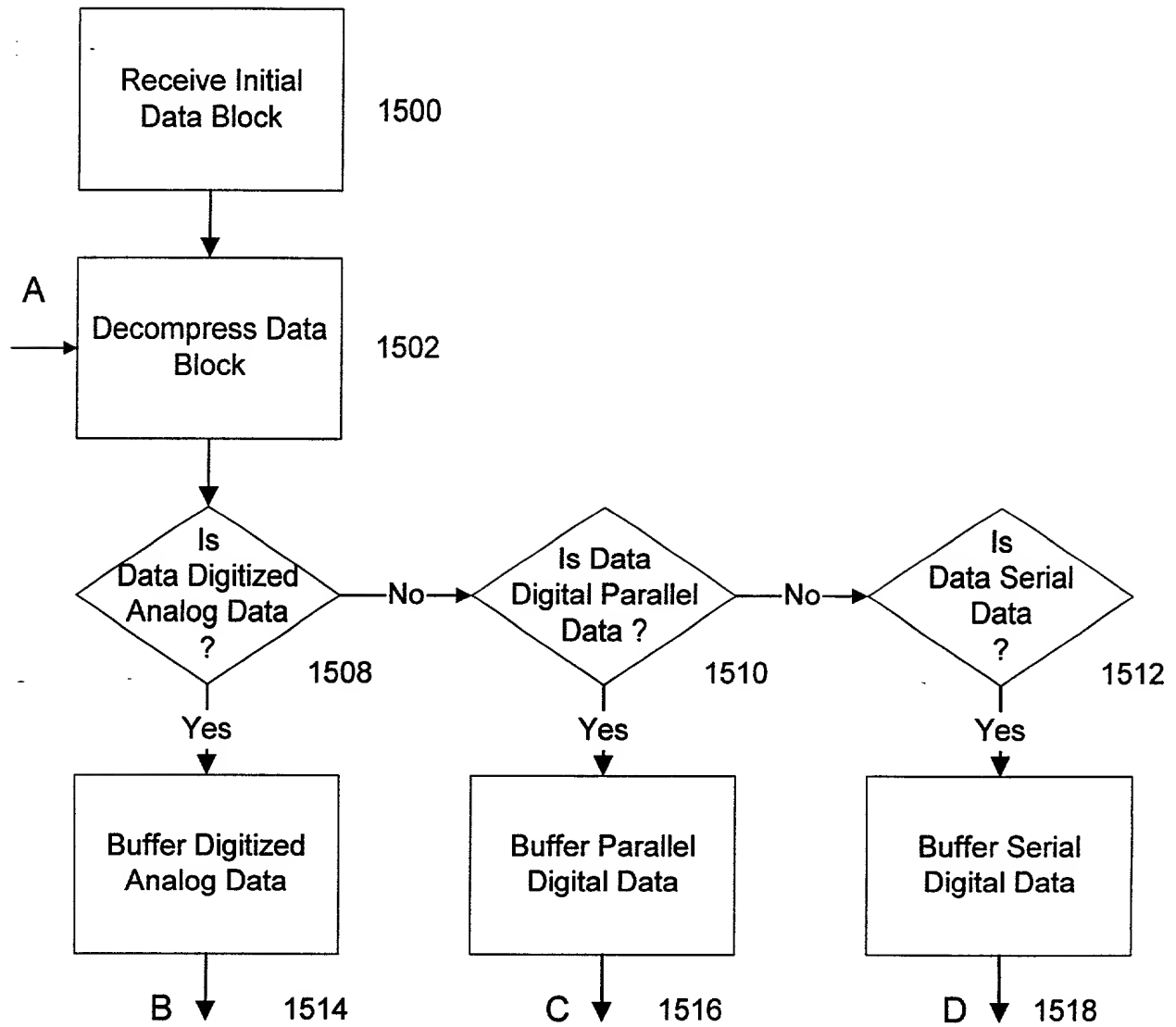


FIGURE 15a

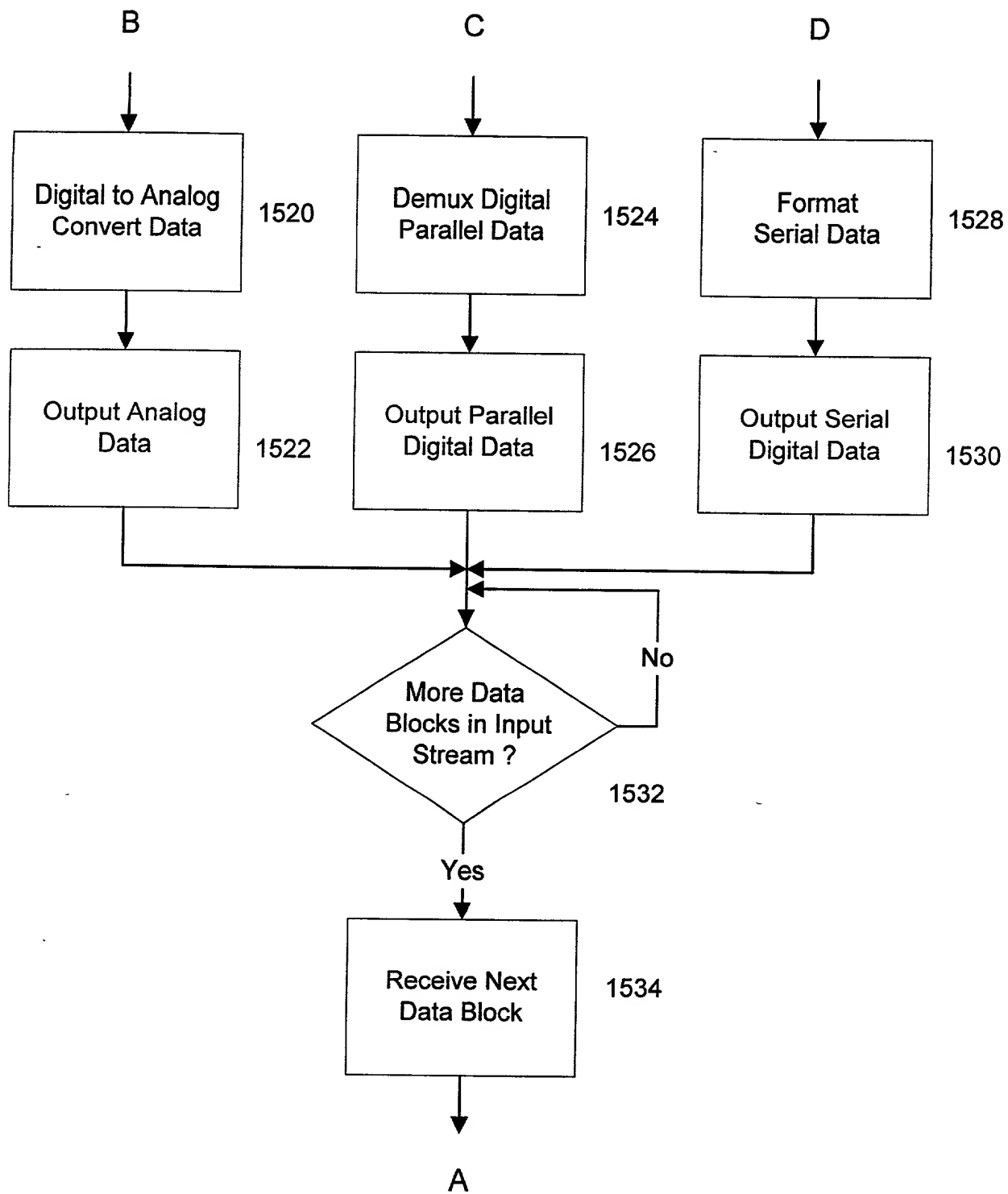


FIGURE 15b

AS A BELOW NAMED INVENTOR, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe that I am the original, first and sole (*if only one name is listed below*), or an original, first and joint inventor (*if plural names are listed below*), of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE: SYSTEM AND METHODS FOR ACCELERATED DATA STORAGE AND RETRIEVAL

the specification of which either is attached hereto or indicates an attorney docket no. 8011-2, or:

☐ was filed in the U.S. Patent & Trademark Office on _____ and assigned Serial No. _____,

☐ and (*if applicable*) was amended on _____,

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability and to the examination of this application in accordance with Title 37 of the Code of Federal Regulations §1.56. I hereby claim foreign priority benefits under Title 35, U.S. Code §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designated at least one country other than the United States, or §119(e) of any United States provisional application(s), listed below and have also identified below any foreign applications for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Priority Claimed:

Yes [] No []

(Application Number) (Country) Day/Month/Year filed)

Yes [] No []

(Application Number) (Country) (Day/Month/Year filed)

I hereby claim the benefit under Title 35, U.S. Code, §120, of any United States application(s), or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of Title 35, U.S. Code, §112, I acknowledge the duty to disclose information material to patentability as defined in Title 37, The Code of Federal Regulations, §1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial Number) (Filing Date) (STATUS: patented, pending, abandoned)

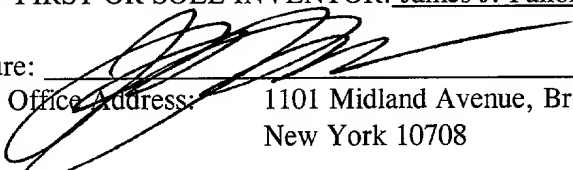
(Application Serial Number) (Filing Date) (STATUS: patented, pending, abandoned)

I hereby appoint the following attorneys: **FRANK CHAU**, Reg. No. 34,136; and **JAMES J. BITETTO**, Reg. No. 40,513, each of them of **F. CHAU & ASSOCIATES, LLP**, 1900 Hempstead Turnpike, Suite 501, East Meadow, New York 11554 to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith and with any divisional, continuation, continuation-in-part, reissue or re-examination application, with full power of appointment and with full power to substitute an associate attorney or agent, and to receive all patents which may issue thereon, and request that all correspondence be addressed to:

Frank Chau, Esq.
F. CHAU & ASSOCIATES, LLP
1900 Hempstead Turnpike, Suite 501
East Meadow, New York 11554
Area Code: 516-357-0091

I HEREBY DECLARE that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 U.S. Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's signature: 

Date: 3/2/87

Residence & Post Office Address: 1101 Midland Avenue, Bronxville
New York 10708

FULL NAME OF SECOND INVENTOR: _____ Citizenship _____

Inventor's signature: _____ Date: _____

Residence & Post Office Address: _____

FULL NAME OF THIRD INVENTOR: _____ Citizenship _____

Inventor's signature: _____ Date: _____

Residence & Post Office Address: _____

FULL NAME OF FOURTH INVENTOR: _____ Citizenship _____

Inventor's signature: _____ Date: _____

Residence & Post Office Address: _____

FULL NAME OF FIFTH INVENTOR: _____ Citizenship _____

Inventor's signature: _____ Date: _____

Residence & Post Office Address: _____

FULL NAME OF SIXTH INVENTOR: _____ Citizenship _____

Inventor's signature: _____ Date: _____

Residence & Post Office Address: _____

FULL NAME OF SEVENTH INVENTOR: _____ Citizenship _____

Inventor's signature: _____ Date: _____

Residence & Post Office Address: _____